NATIONAL ENERGY TECHNOLOGY LABORATORY

Office of Fossil Energy
SECA Solid State Fuel Cells
Clean Economic Energy in a Carbon Challenged World

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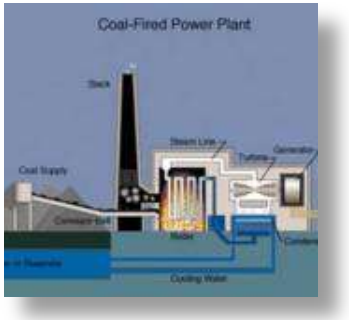
United States Department of Energy

Revolutionizing Power Production & Use

SECA as a key part of DOE's Strategy to Reduce Electrical Energy Losses

Current Technology

Coal Generation



35% Efficiency
(65% Loss)

Transmission & Distribution

31% Efficiency
(11% Loss)

End-Use
Light

4% Efficiency
(87% Loss)

DOE Programs for Tomorrow

Coal Generation

SECA SOFC Systems

60% Efficiency
(40% Loss)

SMART GRID

55% Efficiency
(8% Loss)

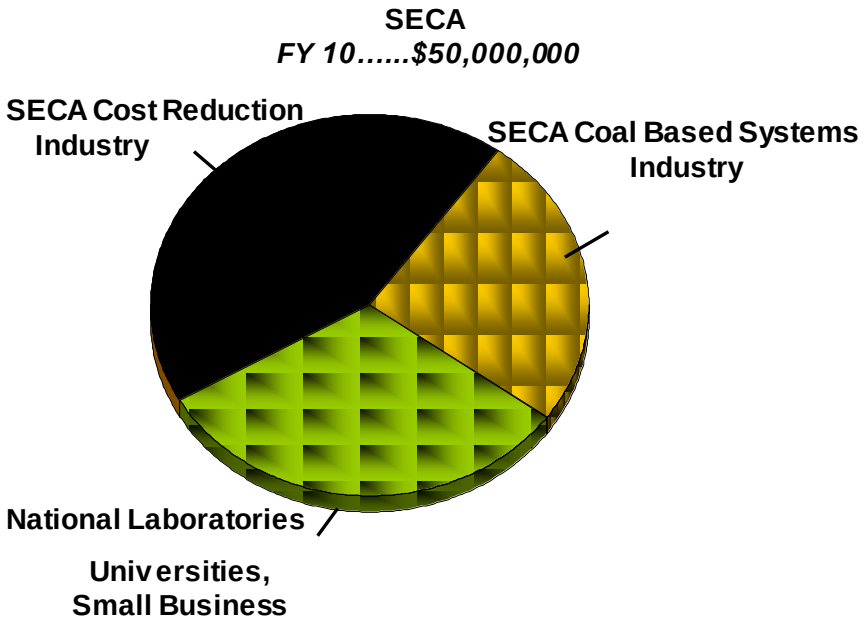
Solid-State Lighting

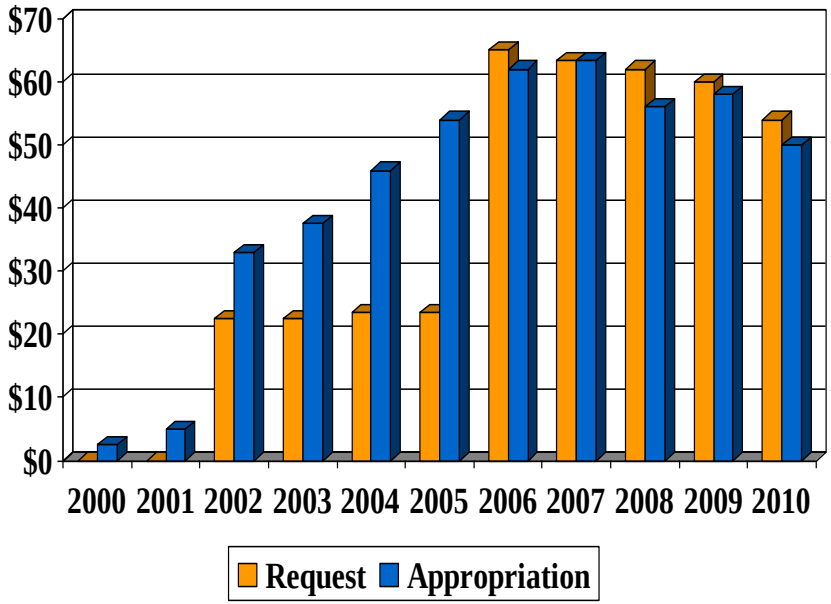
>40% Efficiency
(27% Loss)

SECA and other DOE programs can realistically increase end-use efficiency by more than 10x! (from 4 to >40)

Adapted from AEP, Ohio Fuel Cell Coalition, June 2009

FY 10 Fossil Energy Fuel Cell Program Solid State Energy Conversion Alliance (SECA)





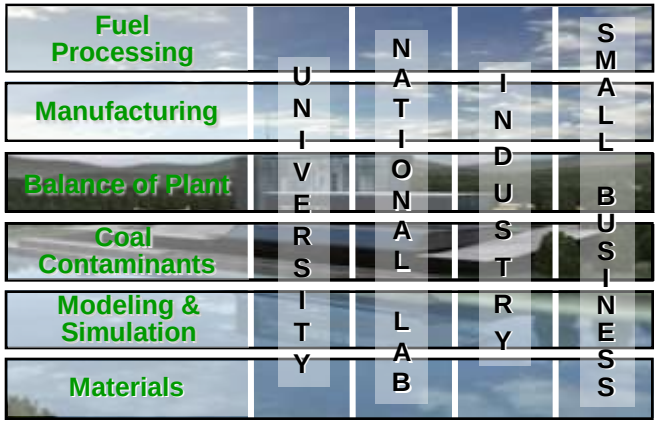
SECA Program Structure

Project Management

Needs → *Research Topics*

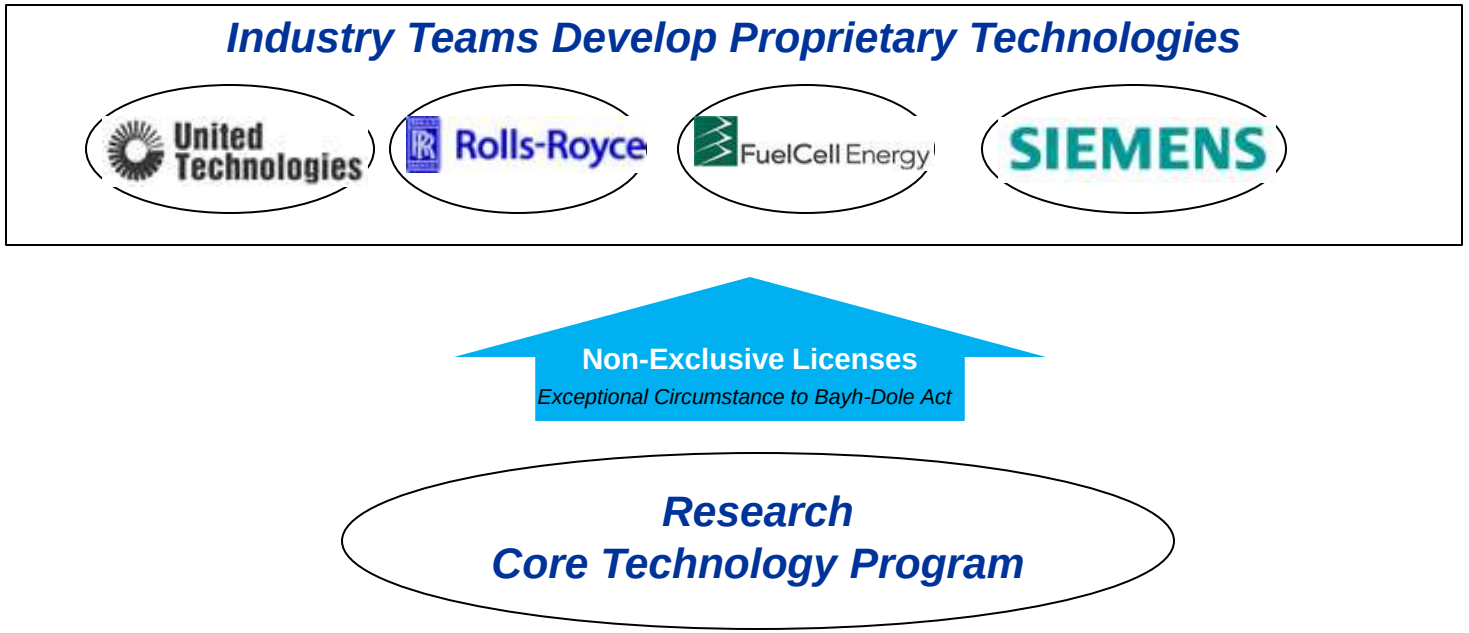
Industry Integration Teams

Technology Transfer



Core Technology Program

Intellectual Property
Cornerstone of the Alliance

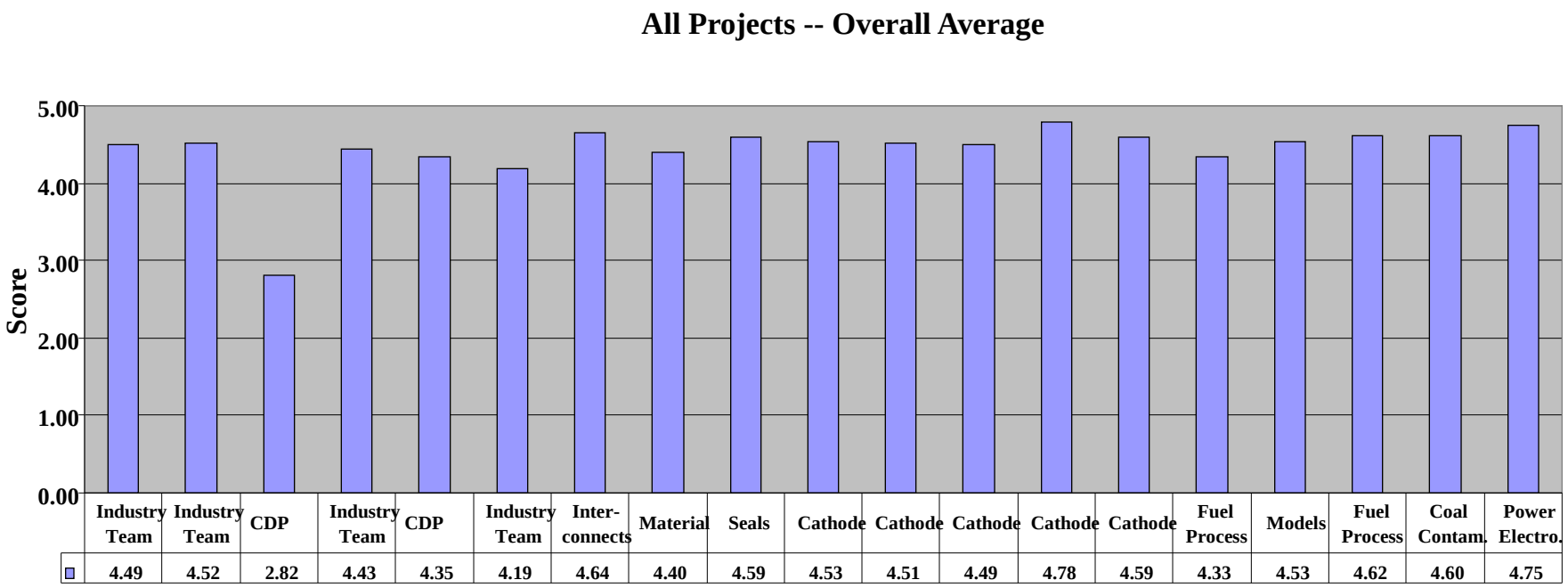


- **Promotes Collaboration – Industry knows it will benefit**
- **Limits Research Redundancy – Less Government Dollars**
- **Technology in best designs – Technology isn't "locked up"**

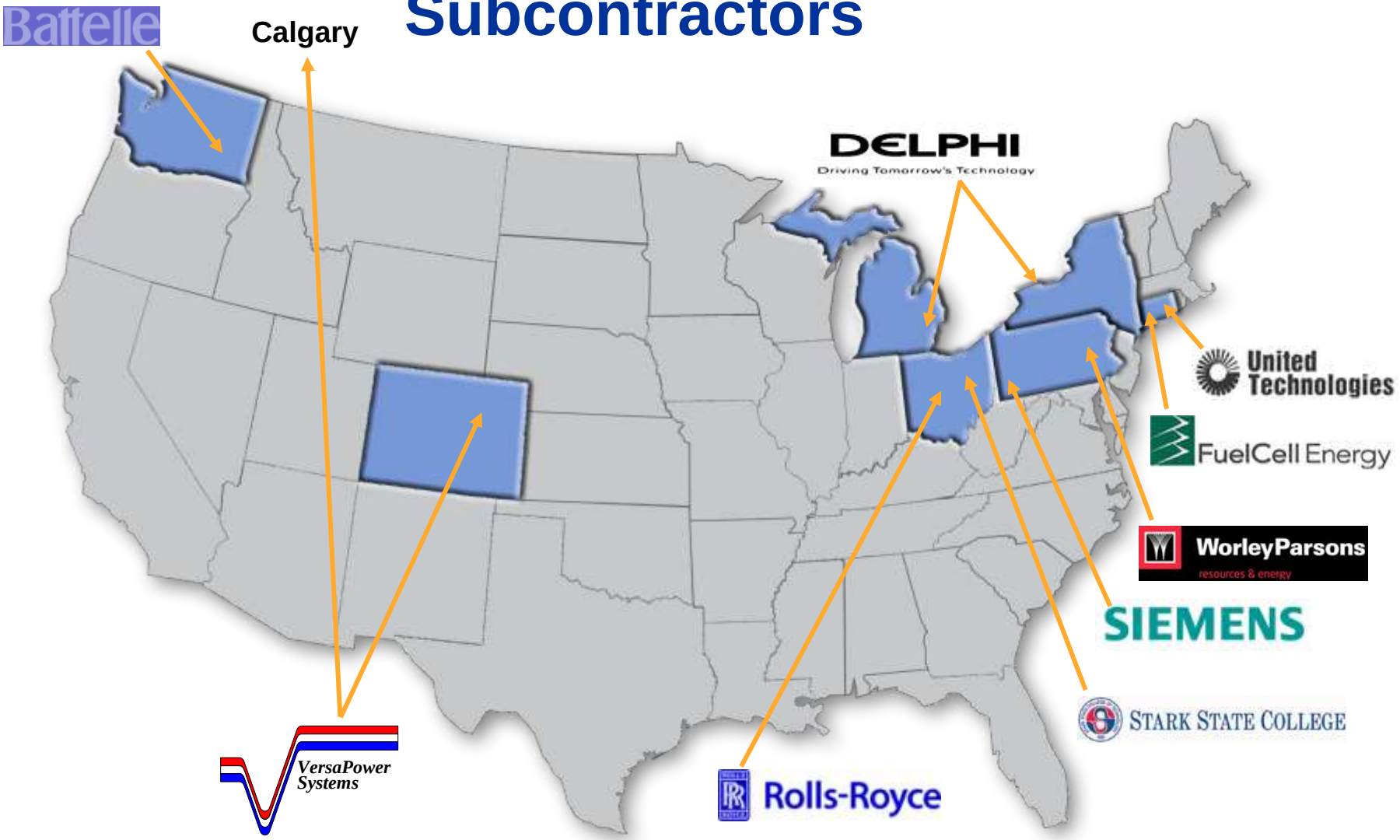
OMB cited SECA as Leading the Way in Government-Industry Partnerships

- **The Office of Management and Budget cited the SECA program as leading the way in Government-industry partnerships. "*The SECA program leverages private-sector ingenuity by providing Government funding to Industry Teams developing fuel cells, as long as the Teams continue to exceed a series of stringent technical performance hurdles. This novel incentive structure has generated a high level of competition between the Teams and an impressive array of technical approaches. The SECA program also develops certain core technologies that can be used by all the Industry Teams to avoid duplication of effort. The program exceeded its 2005 performance targets, and it is on track to meet its goal for an economically competitive technology by 2010*."**

SECA Peer Review 2008
Project Average Score Results



SECA Industry Teams & Major Subcontractors



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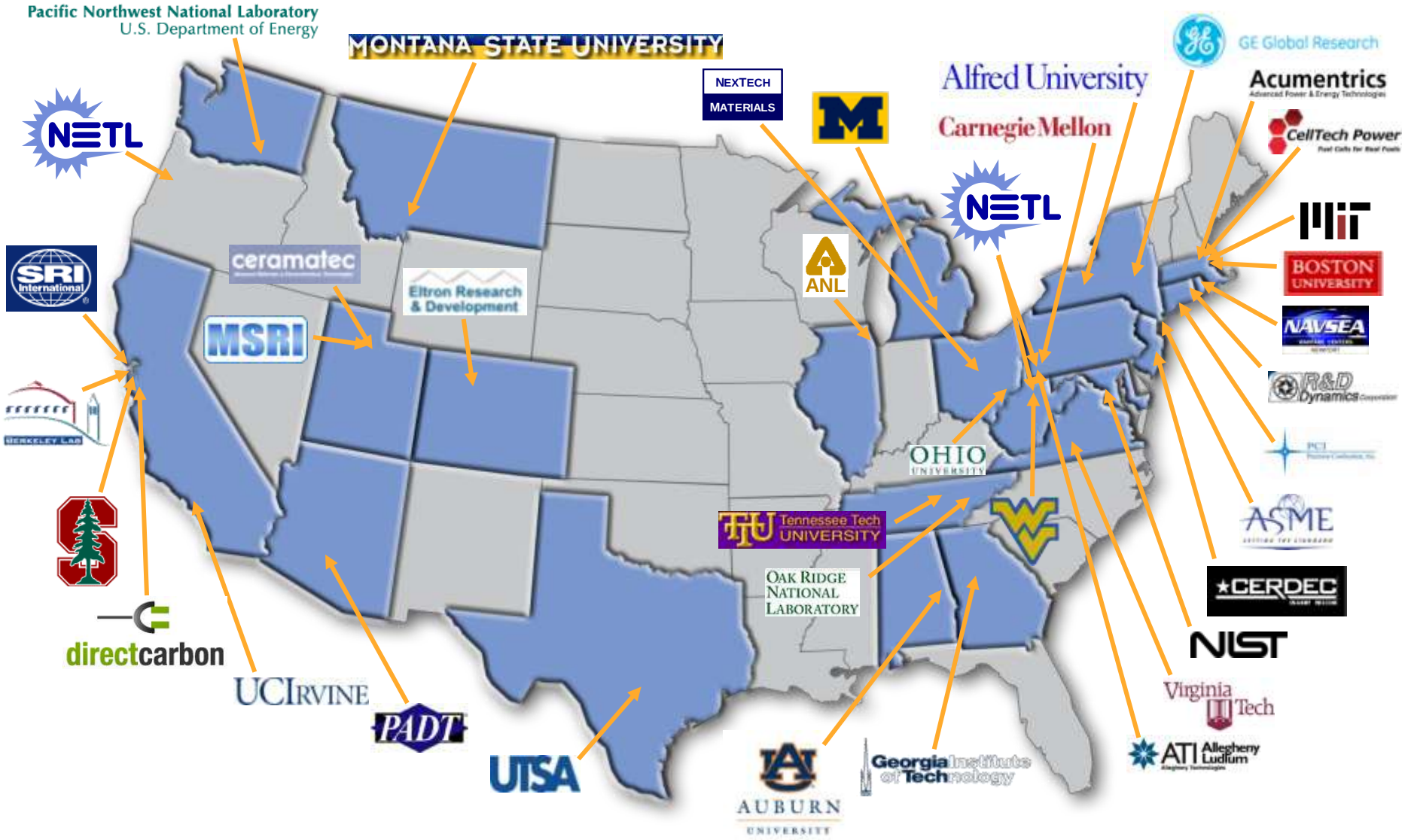
2009 SECA Core Technology & Other Partners



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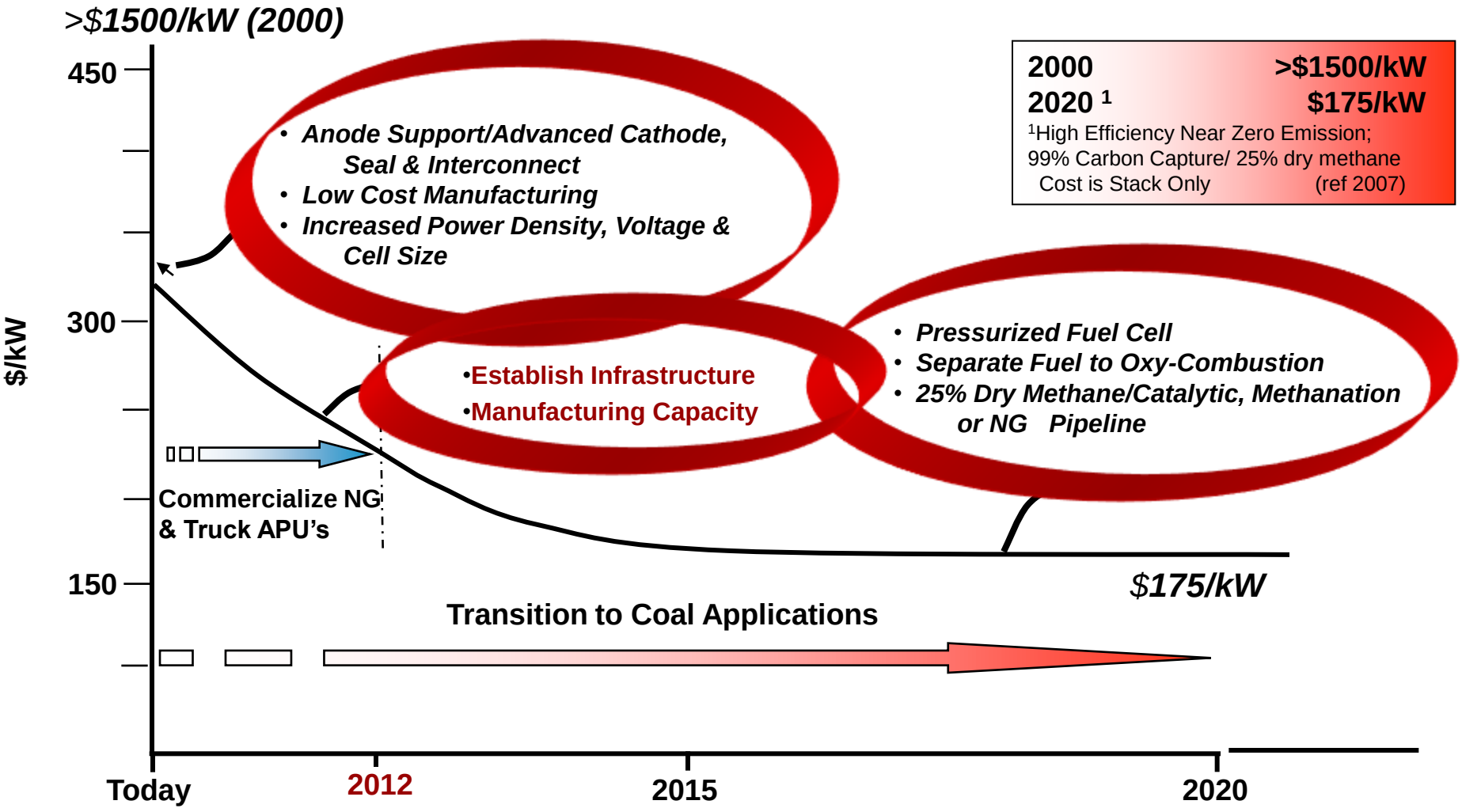
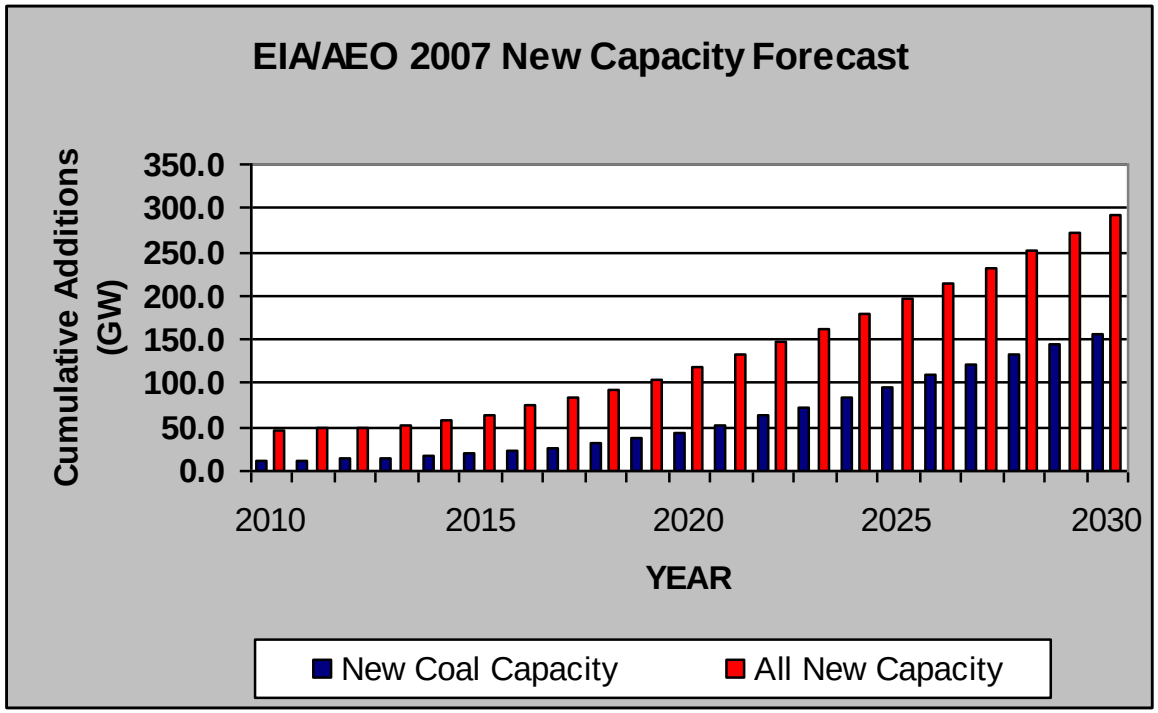
Driving Down Costs For Fuels Cells(1)

(Order of Magnitude Cost Reduction)



How Big are the U.S. Markets? Coal



SECA Fuel Cells available for installation in 2018
New Coal Capacity, 2018 – 2030…….110 GW
Average SECA Fuel Cell Production …. 9.2 GW/yr

EIA Annual Energy Outlook (AEO) for 2007 pp. 82-83

DOE's Office of Fossil Energy

Advanced (Coal) Power Systems Goals

- **2010:**
  - **45-50% Efficiency (HHV)**
  - **99% SO_2 removal**
  - **NOx< 0.01 lb/MM Btu**
  - **90% Hg removal**
- **2012:**
  - **90% CO_2 capture**
  - ***<10% increase in COE with carbon sequestration***
- **2015**
  - **Multi-product capability (e.g, power + H_2)**
  - **60% efficiency (measured without carbon capture)**

Solid State Energy Conversion Alliance Performance Assessment Rating Tool (OMB) 2010

SECA

Stack Cost ~ $175/kW stack

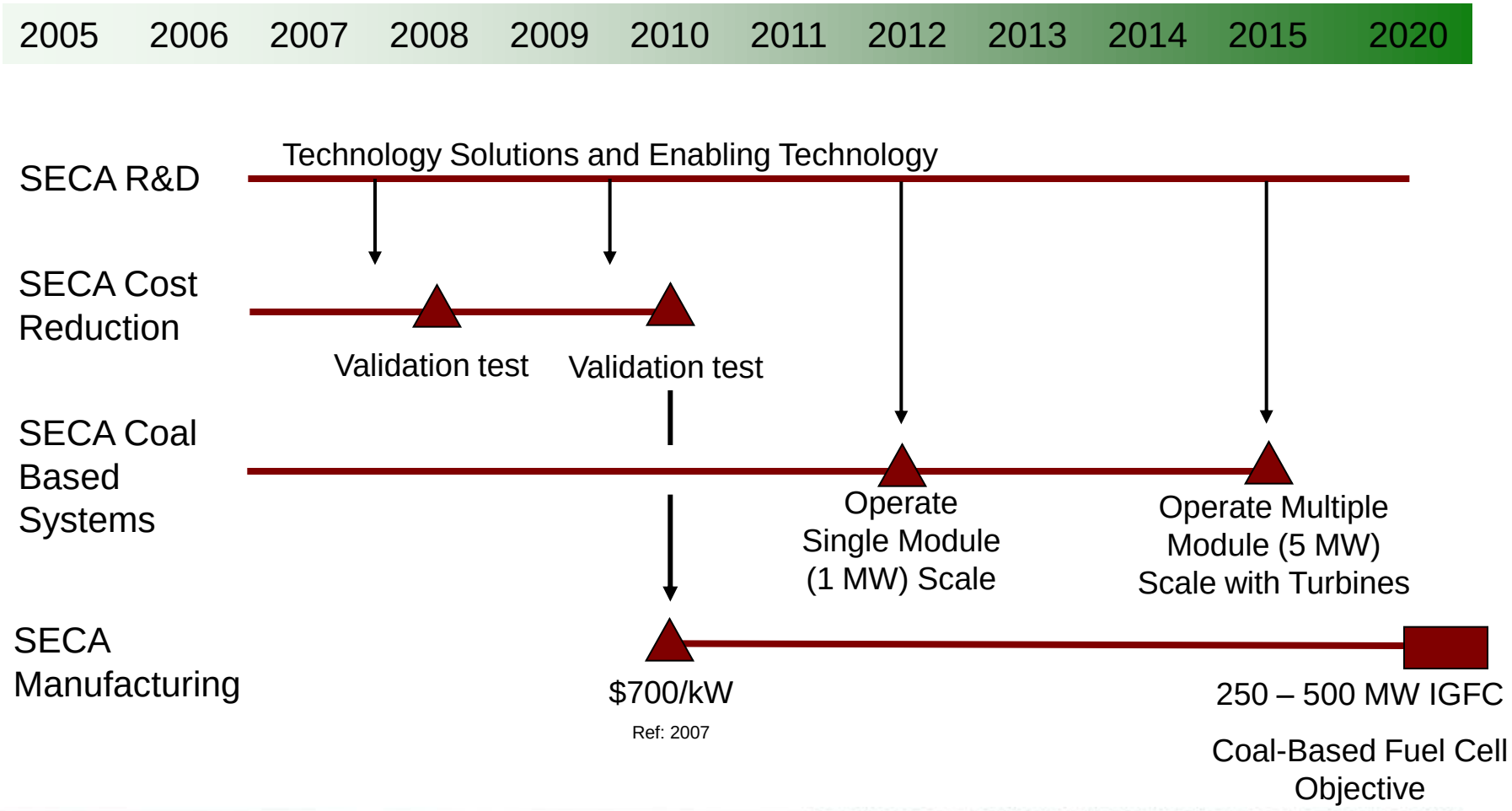
Capital Cost < $700/kW system

Maintain Economic Power Density with Increased Scale ~ 300mW/cm2

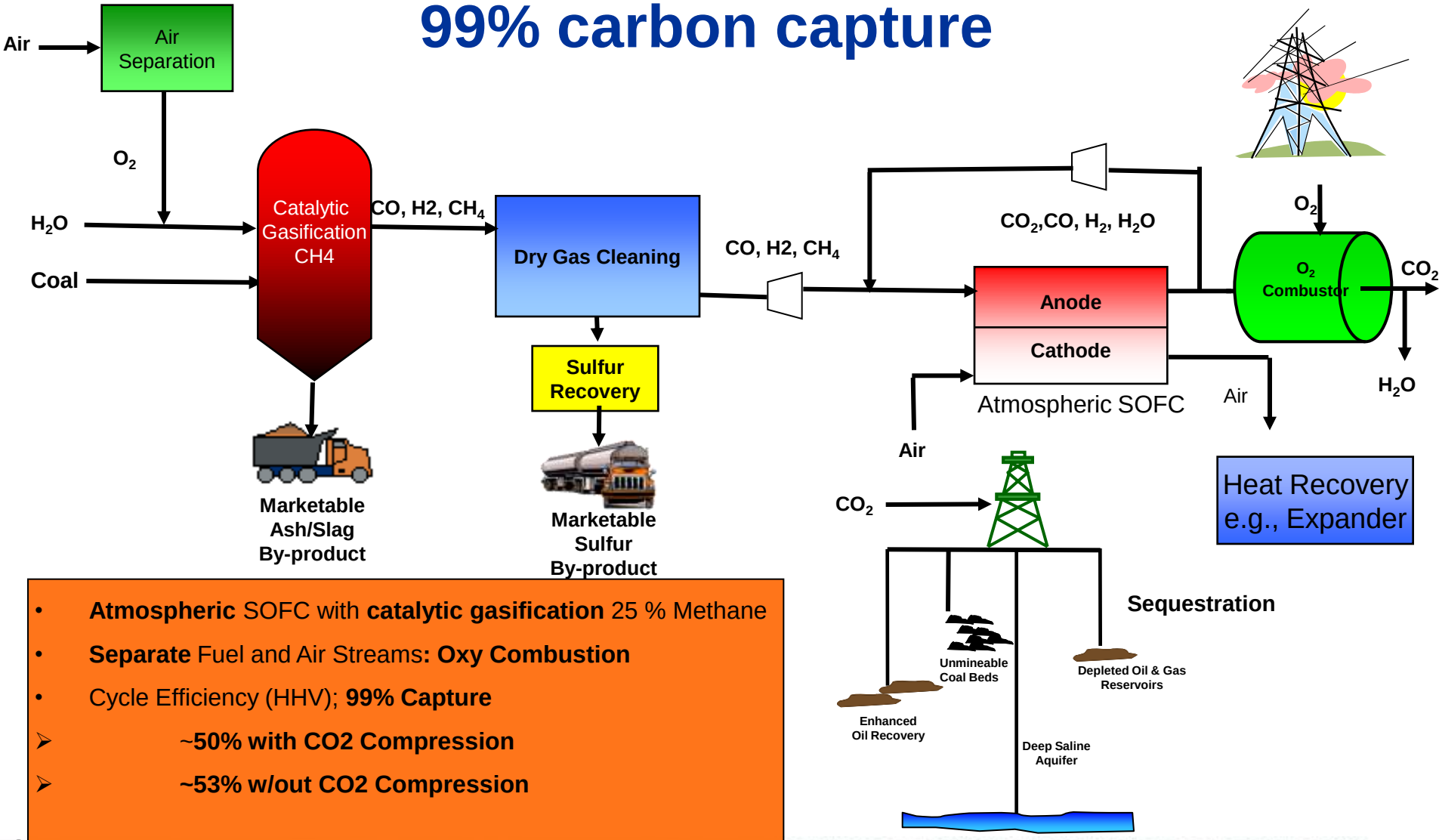
Ref: 2007
Goal: 2010

Mass customization – stacks used in multiple applications….large and small systems

Solid State Energy conversion Alliance Fuel Cells Technology Timeline

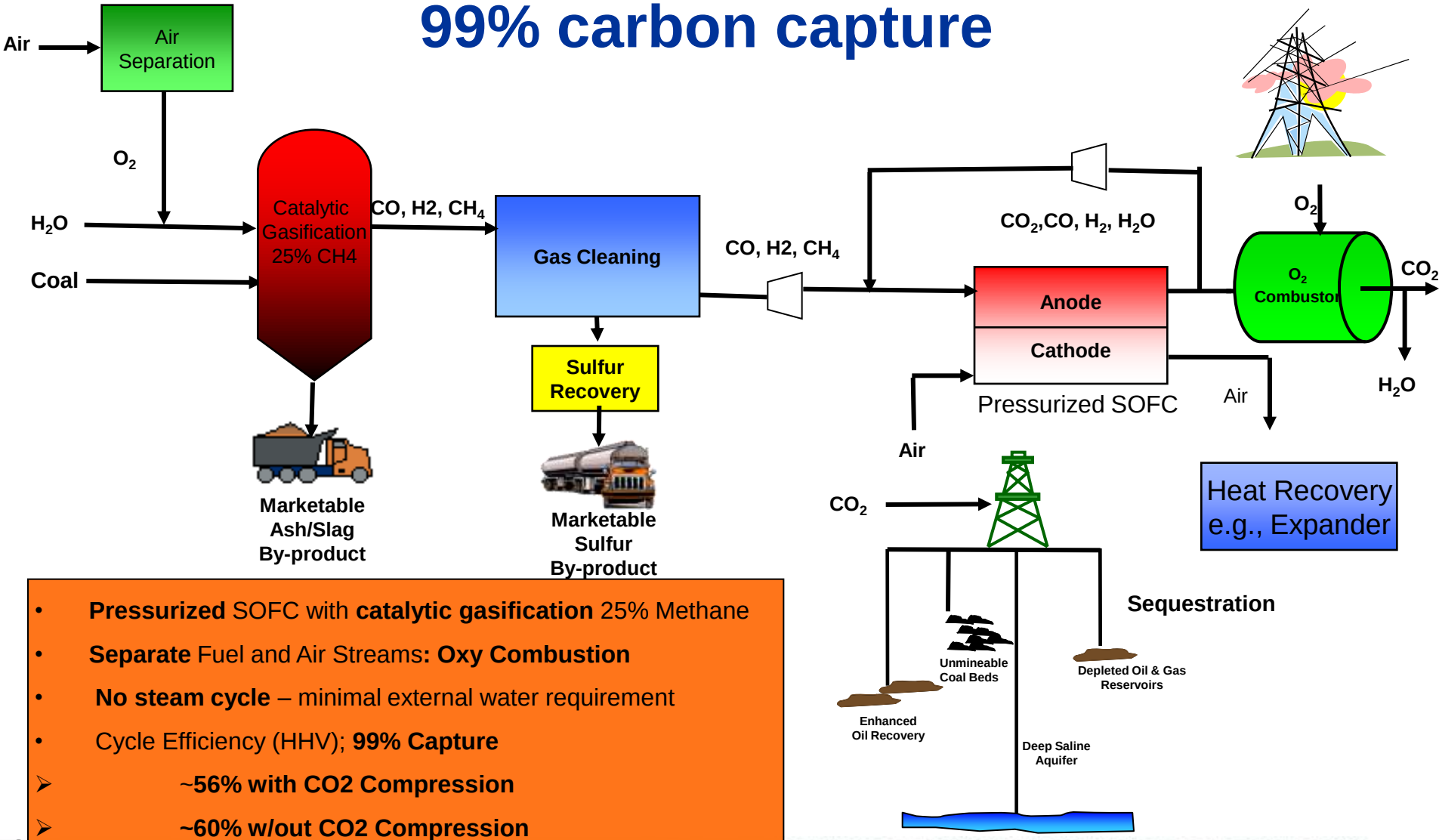


SECA Coal Based Systems near-zero water requirement 99% carbon capture



- **Atmospheric** SOFC with **catalytic gasification** 25 % Methane
- **Separate** Fuel and Air Streams**: Oxy Combustion**
- Cycle Efficiency (HHV); **99% Capture**
  - **~50% with CO2 Compression**
  - **~53% w/out CO2 Compression**

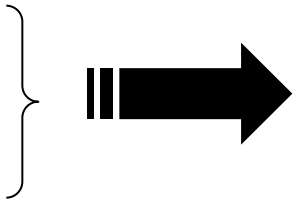
SECA Coal Based Systems
near-zero water requirement
99% carbon capture



- **Pressurized** SOFC with **catalytic gasification** 25% Methane
- **Separate** Fuel and Air Streams**: Oxy Combustion**
- **No steam cycle** – minimal external water requirement
- Cycle Efficiency (HHV); **99% Capture**
  - **~56% with CO2 Compression**
  - **~60% w/out CO2 Compression**

Key Points

- **25% Methane**
  +
- **Pressure**



60% Efficiency HHV

- **Separate Air & Fuel Streams / no Steam Plant**

➢ **99 % Carbon Capture**

➢ **Near Zero Water Use**

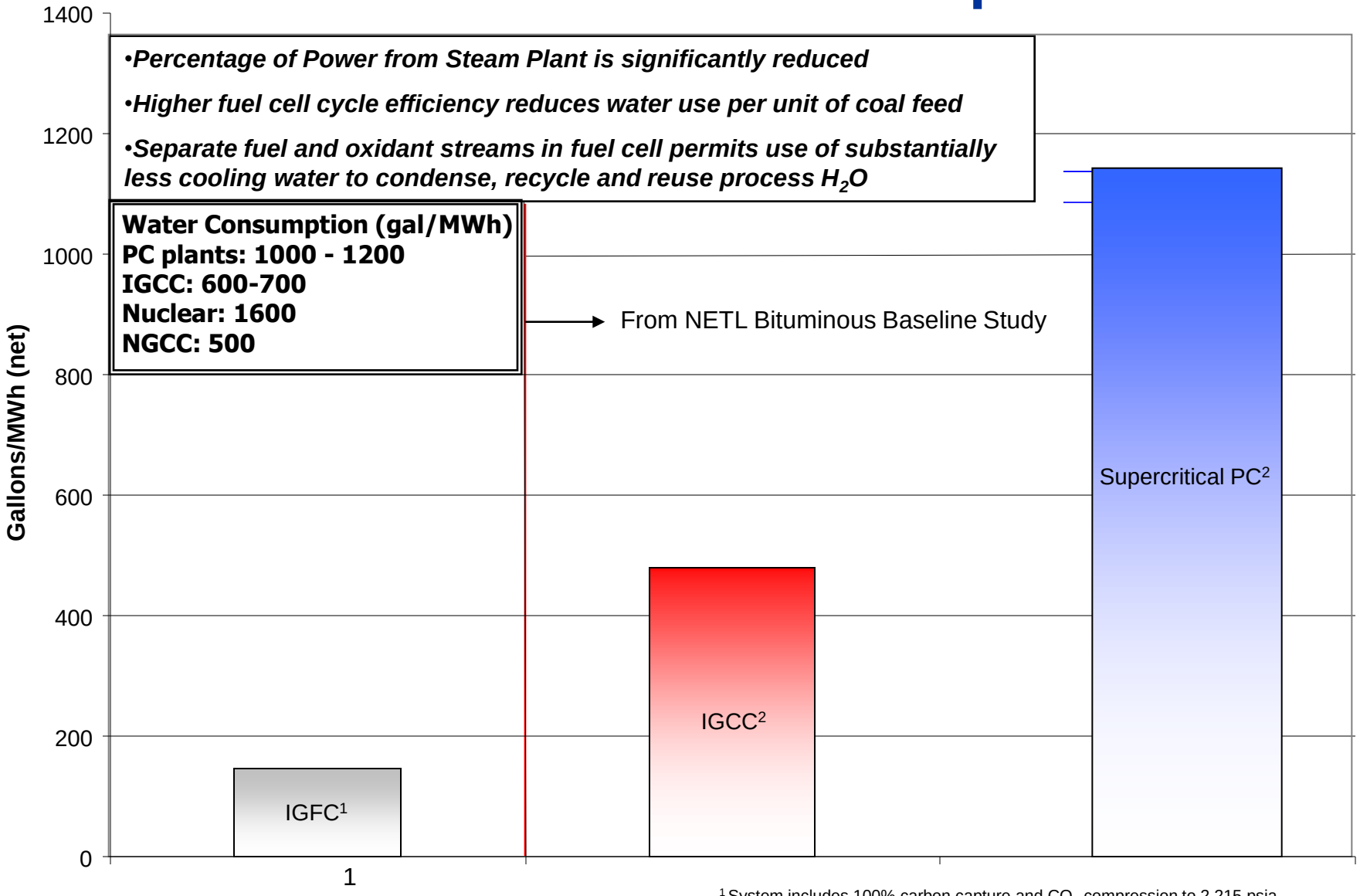
➢ **< 0.5 ppm NO_x**

Impact of Efficiency on COE

Advanced Power Systems With CO_2 Capture, Compression and Storage				
	PC Baseline	IGCC Baseline	IGFC Atmos.	IGFC Press.
Efficiency HHV (%)	27.2	32.5	50.0	57.3
Capital Cost $/kW	2,870	2,390	1,991	1,667
Steam Cycle % Power	100	37	26	2
Cost-of-Electricity ¢/kW-hr	11.6	10.6	8.5	7.3

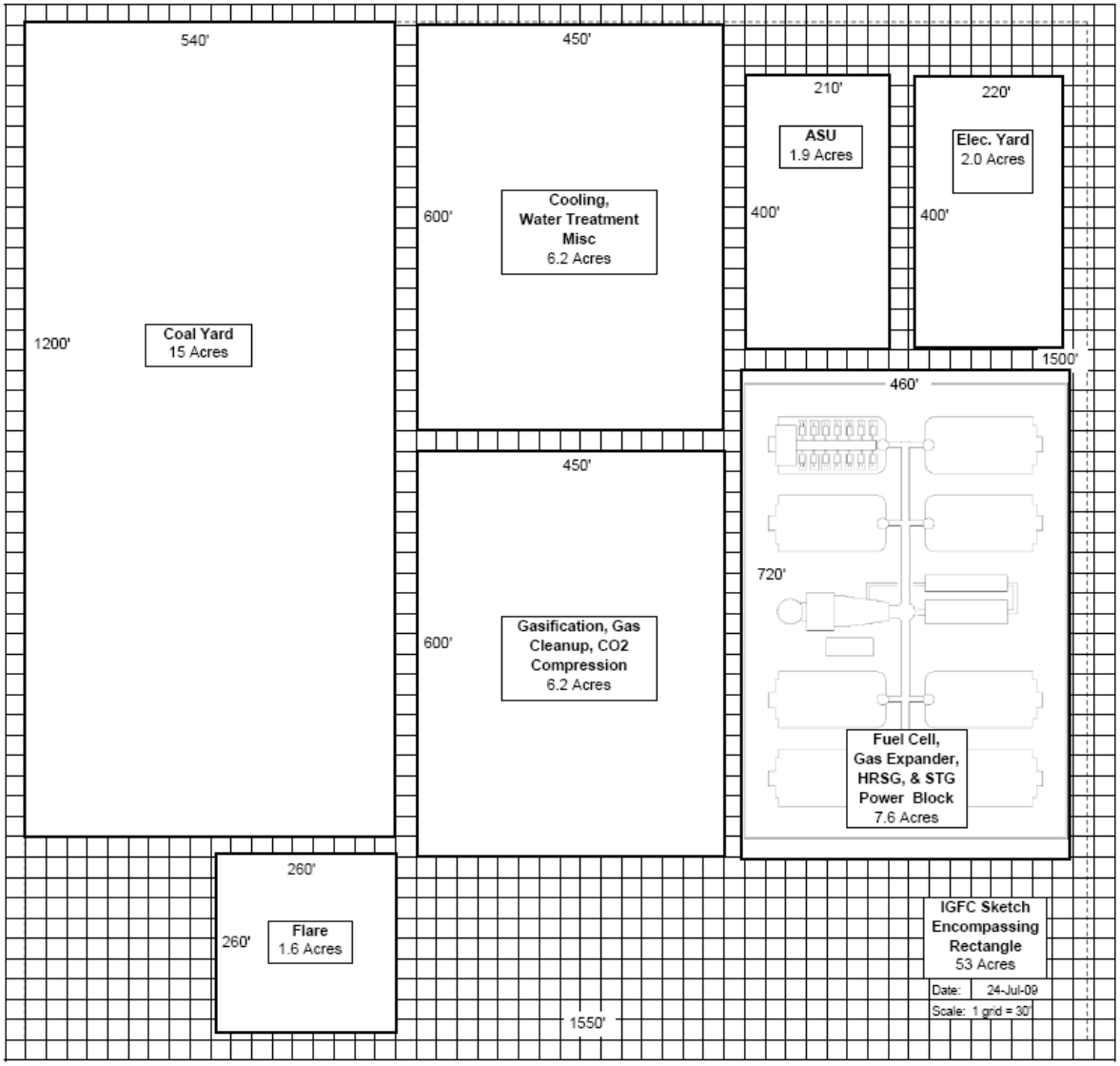
The Benefit of SOFC for Coal Based power Generation, Report Prepared for U. S. Office of Management and Budget, 30OCT07

Raw Water Withdrawal Comparison



[1] System includes 100% carbon capture and CO_2 compression to 2,215 psia
[2] System includes 90% carbon capture and CO_2 compression to 2,215 psia

IGFC Plot Plan



Provided by:

WorleyParsons

resources & energy

Preliminary Footprint Comparison: IGFC : IGCC

IGFC [Integrated Gasification Fuel Cell Cycle]

IGCC [Integrated Gasification combined Cycle]

- IGFC process area size reduction associated with the increased plant efficiency (coal yard, ASU, gasification, syngas cleanup, CO_2 compression, cooling system)
- IGFC process area size increases (power block)
- IGFC process areas is independent (electric switchyard, general services, parking, laydown)

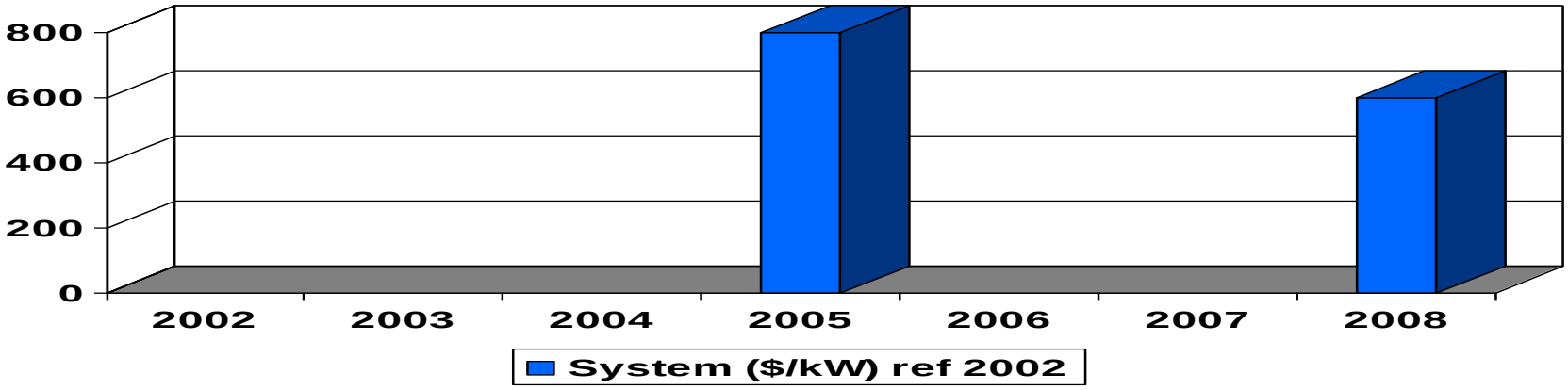
Plant Capacity – 500 MW	IGCC	IGFC
Preliminary Foot Print	Range: 50 -100 acres	~53 acres Range: 50-100 acres

Conclusion: IGCC and IGFC will be comparable in real estate requirement.

Provided by: WorleyParsons resources & energy

Single Cell Module Performance
Planar Cell - Atmospheric

						(x10)
250mw/cm²@ 0.6 V 144 cm²	275mw/cm²@ 0.7V 144cm²	400mw/cm²@ 0.7V 144cm²	450mw/cm²@ 0.7V 144cm²	600mw/cm²@ 0.7V 144cm²	500mw/cm²@ 0.8V 144 cm²	450mw/cm²@ 0.85V 550 cm²



Research Priorities:
SECA Cost Reduction and Coal Systems

Risk Level

Low

Medium

High

	Gas Seals	▪ Glass and Compressive Seals ▪ Compliant Seals ▪ Self-healing Materials ▪ High Temperature Refractive Seal
	Failure Analysis	▪ Models with Electrochemistry & EMF ▪ Define Operating Window (Not possible experimentally) ▪ Structural Failure Analysis & Design Criteria (ASME)

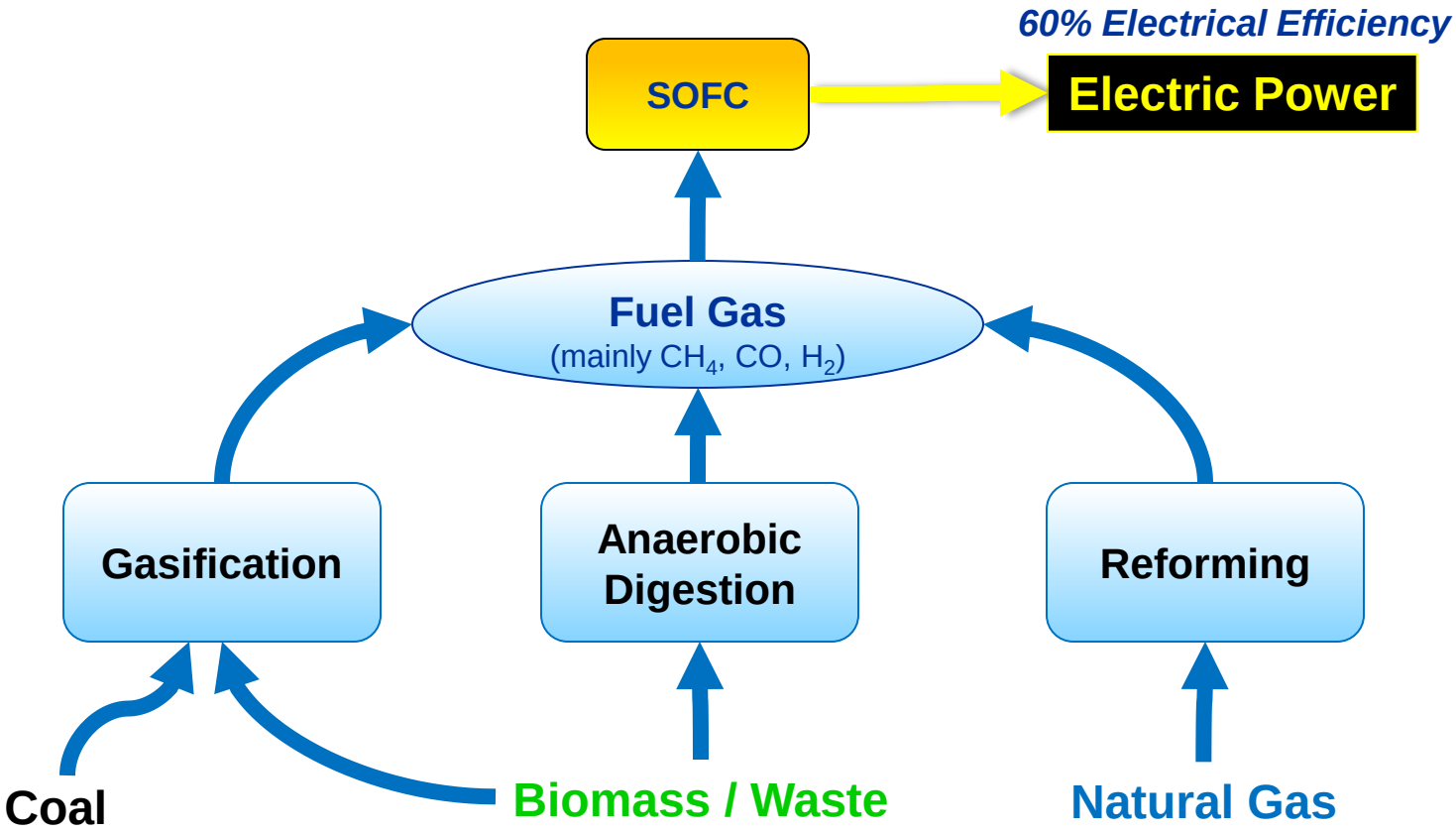
	Cathode performance	▪ Understand Mechanism
		  ▪ Ad-atom Modification of Surfaces
		  ▪ Modification through Infiltration

	Interconnect	▪ Coatings ▪ Electrode to Interconnect Interface - Contact Material
	Anode / fuel processing	▪ Establish Fuel Specification ▪ Characterize Thermodynamics/Kinetics/ Contaminants
	Heat Exchangers/ High Temperature Blowers	▪ Cost and Reliability ▪ Design Guidelines

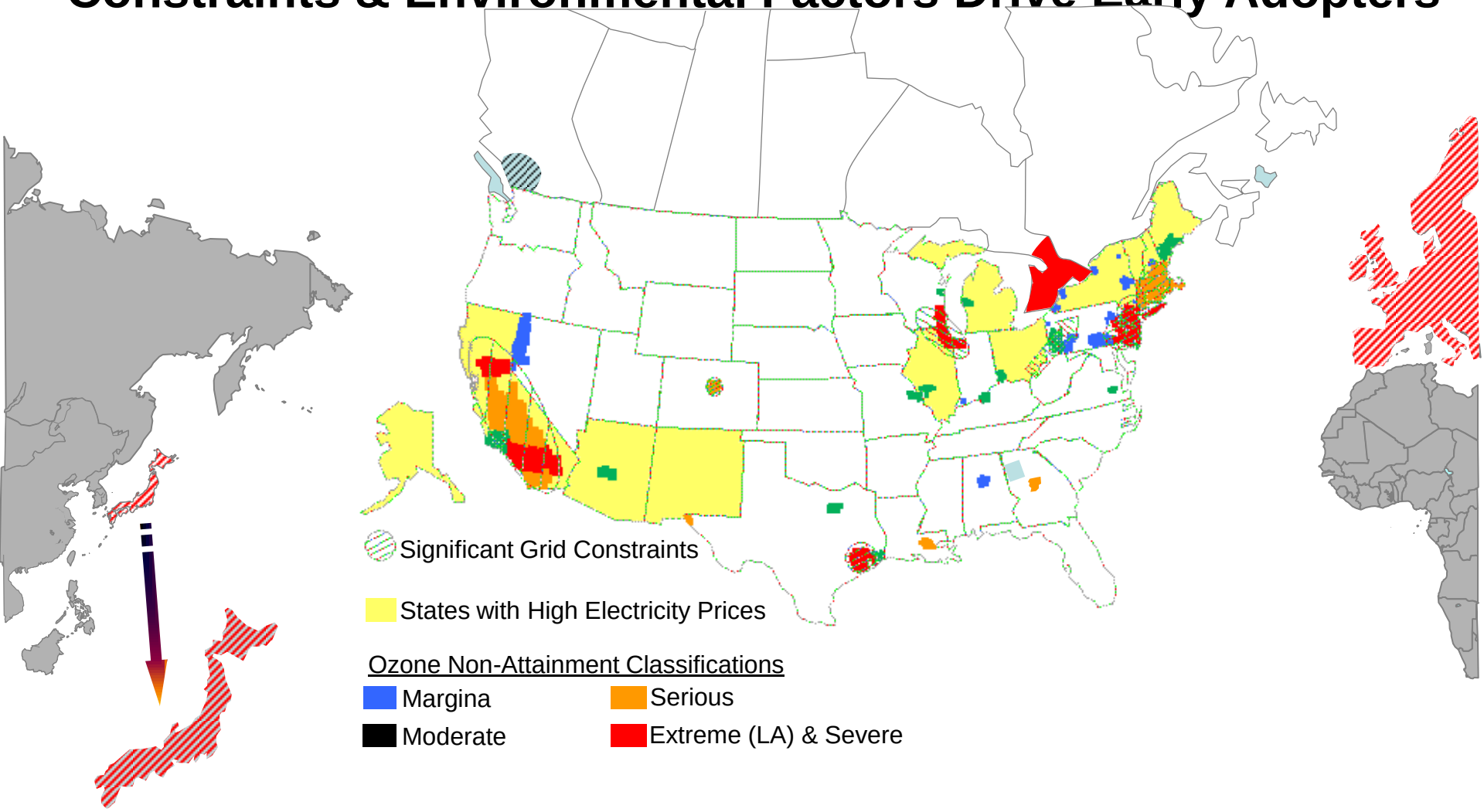
Electronic Effect versus Defect Chemistry

SECA Solid Oxide Fuel Cells

SECA systems can produce power from any commercial fuel



Convergence of Power Demand, High Power Cost, Grid Constraints & Environmental Factors Drive Early Adopters



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Source: Energy Information Administration

SECA U.S. Markets/Distributed Generation 7 GW/yr

	Power Range	Units per year		Total (GW/yr)
Remote Generators	3-10 kW	30,000		0.195
Telecommunications	3-10 kW	30,000		0.195
Commercial/Industrial	1 – 5 MW	1,000		3.0
Back-up Power	5 – 250 kW	10,000		1.27
Auxiliary Power Units (Trucks)	5-15 kW	200,000		2.0
		Annual Capacity		6.6

Peterbilt/Delphi Auxiliary Power Unit
Commercial in 2012

Pathway to Coal Plants

•Development Similar to Computer Commercialization

Central Main Frame > Small Laptop > Large Parallel Computing

Fuel Cells: 200kW (1990's) to 5kW (2007) to 5MW (2015) to 500 MW (2020)

•Develops Infrastructure for Fuel Cell Stack Manaufacture

- **Delphi's diesel SECA APU powered the Peterbilt Model 386's electrical hotel loads, including air-conditioner, radio, CB, lights, battery, & start-up.**
- **The Delphi SECA APU addresses anti-idling regulations by reducing idling emissions. (30% efficiency versus 7% for primary engine)**

SOFCs in Unmanned Undersea Vehicles (UUVs)

21UUV (2-5 kW)
- **Fisher-Tropsch**
- **SECA Stacks and Blower**

- **Naval Undersea Warfare Center, Division Newport, (NUWCDIVNPT) successfully tested SECA SOFCs in extreme conditions. Used SECA Stacks (2 Developers) and SECA developed High Temperature Blower**
- **SOFC technology has the potential to greatly increase UUV mission time compared with current battery technology.**
- **Although SECA has a coal-based, central generation focus, spin-off applications are encouraged. Military applications like UUVs provide operating experience and independent validation for SECA.**
- **Cost and operational lifetime are not necessarily major concerns for military applications, as long as new mission capability can be delivered.**

For More Information About the DOE Office of Fossil Energy Fuel Cell Program

Websites:

www.netl.doe.gov
www.fe.doe.gov
www.grants.gov

CDs available from the website

- **10th Annual SECA Workshop Proceedings (2009)**
- **Fuel Cell Handbook (7th ed.)**

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